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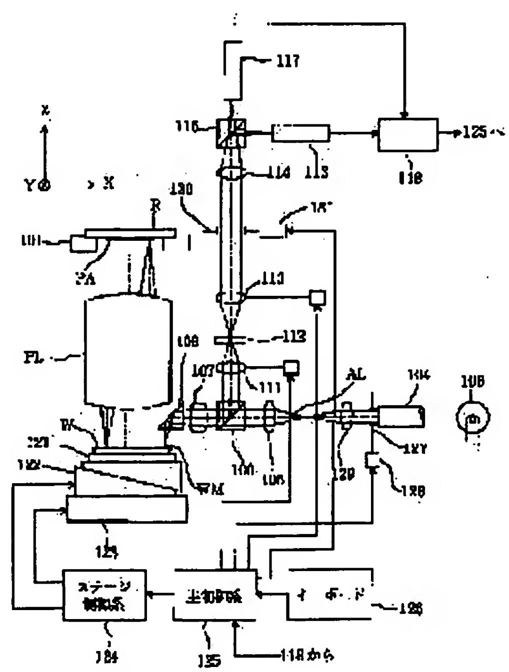
(54) APPARATUS AND METHOD FOR INSPECTING OPTICAL SYSTEM, ALIGNER HAVING THE INSPECTING APPARATUS AND PROJECTION ALIGNER

(57)Abstract:
PROBLEM TO BE SOLVED: To accurately and easily inspect various astigmatisms, focal positions, optical axis deviations, etc., of an optical system.
SOLUTION: An optical system, having illumination optical systems 103-108 for radiating an illumination light on a phase pattern WM and image forming optical systems 107-115 for forming image of the phase pattern is inspected. It comprises means 116, 117 for detecting the image of the phase pattern formed through this optical system and a means 122 for defocusing the image of the phase pattern detected in the image inspecting means. The coma aberration of the optical system, shading of the light flux in the optical system and inclination of the main light beam of the illumination light with respect to the normal to a phase pattern forming plane W are inspected, based on the change in the asymmetry of an image corresponding to the edge of the phase pattern which is respectively detected in a defocused condition in the image detecting means.



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CLAIMS

[Claim(s)]
[Claim 1] In the test equipment which inspects the optical system which has the image formation optical system for condensing the flux of light from the illumination-light study system and said phase pattern for irradiating the illumination light to a phase pattern, and carrying out image formation of the image of said phase pattern to it The image detection means for detecting the image of said phase pattern formed through said optical system, The defocusing means for making the image of said phase pattern detected in said image detection means defocus, In said image detection means, it is based on an asymmetric change of the image corresponding to the edge of each of said phase pattern detected in the state of defocusing. Test equipment characterized by having the inspection means for inspecting the inclination of the chief ray of said illumination light to the normal of the forming face of flux of light KERARE in the comatic aberration of said optical system, and said optical system, and said phase pattern.
[Claim 2] In the test equipment which inspects the optical system which has the image formation optical system for condensing the flux of light from the illumination-light study system and said phase pattern for irradiating the illumination light to a phase pattern, and carrying out image formation of the image of said phase pattern to it The image detection means for detecting the image of said phase pattern formed through said optical system, It has a defocusing means for making the image of said phase pattern detected in said image detection means defocus. Said phase pattern The 1st phase pattern which repeats a periodic phase change along the detection direction of said image detection means, It has the 2nd phase pattern with which at least that [this / 1st] has different phase amplitude distribution from a phase pattern, and repeats a periodic phase change along the detection direction of said image detection means. The optical reinforcement of the image of said 1st phase pattern corresponding to the field to which the phase of said 1st phase pattern went, The 1st defocusing location where the optical reinforcement of the image of said 1st phase pattern corresponding to the field in which the phase of said 1st phase pattern was turns into optical predetermined reinforcement, respectively, The optical reinforcement of the image of said 2nd phase pattern corresponding to the field to which the phase of said 2nd phase pattern went, Test equipment characterized by having further the inspection means for inspecting the spherical aberration of said optical system based on the 2nd defocusing location where the optical reinforcement of the image of said 2nd phase pattern corresponding to the field in which the phase of said 2nd phase pattern was turns into optical predetermined reinforcement, respectively.
[Claim 3] In the test equipment which inspects the optical system which has the image formation optical system for condensing the flux of light from the illumination-light study system and said phase pattern for irradiating the illumination light to a phase pattern, and carrying out image formation of the image of said phase pattern to it The image detection means for detecting the image of said phase pattern formed through said optical system, It has a defocusing means for making the image of said phase pattern detected in said image detection means defocus. In said illumination-light study system The lighting opening modification means for changing the amplitude distribution of said illumination light which passes a lighting aperture diaphragm is established. Said phase pattern It is the phase pattern which repeats a periodic phase change along the detection direction of said image detection means. The optical reinforcement of the image of said phase pattern corresponding to the field to which the phase of said phase pattern illuminated under the 1st lighting conditions set up with said lighting opening modification means went, The 1st defocusing location where the optical reinforcement of the image of said phase pattern corresponding to the field in which the phase of said phase pattern was turns into optical predetermined reinforcement, respectively, The optical reinforcement of the image of said phase pattern

corresponding to the field to which the phase of said phase pattern illuminated under the 2nd lighting conditions set up with said lighting opening modification means went, Test equipment characterized by having further the inspection means for inspecting the spherical aberration of said optical system based on the 2nd defocusing location where the optical reinforcement of the image of said phase pattern corresponding to the field in which the phase of said phase pattern was turns into optical predetermined reinforcement, respectively.
[Claim 4] In the test equipment which inspects the optical system which has the image formation optical system for condensing the flux of light from the illumination-light study system and said phase pattern for irradiating the illumination light to a phase pattern, and carrying out image formation of the image of said phase pattern to it The image detection means for detecting the image of said phase pattern formed through said optical system, It has a defocusing means for making the image of said phase pattern detected in said image detection means defocus. Said phase pattern The optical reinforcement of the image of said phase pattern corresponding to the field to which it is the phase pattern which repeats a periodic phase change along the detection direction of said image detection means, and the phase of said phase pattern in each defocusing condition went, It is based on change of a difference with the optical reinforcement of the image of said phase pattern corresponding to the field in which the phase of said phase pattern was. Test equipment characterized by having further the inspection means for inspecting at least one of the focal location of said optical system, the optical-axis top astigmatic difference, astigmatism, a curvature of field, and image surface inclinations.
[Claim 5] The illumination-light study system for irradiating the illumination light at the alignment mark which consists of a phase pattern prepared on the photosensitive substrate with which the image of the alignment mark which consists of a phase pattern prepared on the mask with which the imprint pattern was formed, or said imprint pattern is imprinted, It has the alignment optical system which consists of image formation optical system for condensing the flux of light from said alignment mark, and carrying out image formation of the image of said alignment mark. In the alignment equipment for performing positioning of said mask or said photosensitive substrate Claim 1 for inspecting said alignment optical system thru/or any 1 term of 4 are equipped with the test equipment of a publication. The aberration amendment means for amending the aberration of said image formation optical system based on the inspection information on said alignment optical system by said test equipment, The focus justification means for adjusting the focus location of said image formation optical system based on said inspection information, The image formation aperture-diaphragm justification means for carrying out the relative displacement of the location of the image formation aperture diaphragm of said image formation optical system to an optical axis, in order to amend flux of light KERARE of said image formation optical system based on said inspection information, Alignment equipment characterized by having further at least one of the lighting aperture-diaphragm justification means to which the relative displacement of the location of the lighting aperture diaphragm of said illumination-light study system is carried out to an optical axis in order to amend the inclination of the chief ray of said illumination light to the normal of the body side of said image formation optical system.
[Claim 6] In the projection aligner which equipped the mask with which the imprint pattern was formed with the illumination-light study system for irradiating the illumination light, and the projection optics for forming the image of said imprint pattern on a photosensitive substrate Claim 1 for inspecting said illumination-light study system and said projection optics thru/or any 1 term of 4 are equipped with the test equipment of a publication. The aberration amendment means for amending the aberration of said projection optics based on the inspection information on said illumination-light study system by said test equipment, and said projection optics, The focus justification means for adjusting the focus location of said projection optics based on said inspection information, The image formation aperture-diaphragm justification means for carrying out the relative displacement of the location of the image formation aperture diaphragm of said projection optics to an optical axis, in order to amend flux of light KERARE of said projection optics based on said inspection information, The projection aligner characterized by having further at least one of the lighting aperture-diaphragm justification means to which the relative displacement of the location of the lighting aperture diaphragm of said illumination-light study system is carried out to an optical axis in order to amend the inclination of the chief ray of said illumination light to the normal of the body side of said projection optics.
[Claim 7] In the approach of inspecting optical system including the image formation optical system which forms the image of a predetermined phase pattern Irradiate the illumination light at said phase pattern, and the image of said phase pattern is detected in two or more different defocusing locations in the direction of an optical axis of said image formation optical system. It is based on an asymmetric change of the image

corresponding to the edge of said phase pattern detected in said two or more defocusing locations. The inspection approach of the optical system characterized by inspecting the inclination of the chief ray of said illumination light to the normal of the forming face of flux of light KERARE in the comatic aberration of said optical system, and said optical system, and said phase pattern.
[Claim 8] In the approach of inspecting the optical system which includes the illumination-light study system for irradiating the illumination light, and the image formation optical system which forms the image of said phase pattern in a phase pattern said phase pattern The 1st phase pattern which repeats a periodic phase change along the predetermined direction, Have the phase amplitude distribution in which at least that [this / 1st] differs from a phase pattern, and it has the 2nd phase pattern which repeats a periodic phase change along said predetermined direction. The illumination light is irradiated through said illumination-light study system at said phase pattern. The image of said phase pattern The optical reinforcement of the image of said 1st phase pattern corresponding to the field to which it detected using the image detector which has the detection direction which met in said predetermined direction, and the phase of said 1st phase pattern went, The 1st defocusing location where the optical reinforcement of the image of said 1st phase pattern corresponding to the field in which the phase of said 1st phase pattern was turns into optical predetermined reinforcement, respectively, The optical reinforcement of the image of said 2nd phase pattern corresponding to the field to which the phase of said 2nd phase pattern went, The inspection approach of the optical system characterized by inspecting the spherical aberration of said optical system based on the 2nd defocusing location where the optical reinforcement of the image of said 2nd phase pattern corresponding to the field in which the phase of said 2nd phase pattern was turns into optical predetermined reinforcement, respectively.
[Claim 9] In case said illumination-light study system is constituted possible [modification of the amplitude distribution of said illumination light which passes a lighting aperture diaphragm] and said 1st defocusing location is detected In case the amplitude distribution of said illumination light in said lighting aperture diaphragm is set as the 1st amplitude distribution and said 2nd defocusing location is detected The inspection approach of the optical system according to claim 7 characterized by setting the amplitude distribution of said illumination light in said lighting aperture diaphragm as the 2nd different amplitude distribution from said 1st amplitude distribution.
[Claim 10] In the approach of inspecting optical system including the image formation optical system which forms the image of a predetermined phase pattern Irradiate the illumination light at said phase pattern, and the image of said phase pattern is detected in two or more defocusing locations which are different in the direction of an optical axis of said image formation optical system using the image detector which has the predetermined detection direction. Said phase pattern is a phase pattern which repeats a periodic phase change along the detection direction of said image detector. The optical reinforcement of the image of said phase pattern corresponding to the field to which the phase of said phase pattern in said two or more defocusing locations went, The inspection approach of the optical system characterized by inspecting at least one of the focal location of said optical system, the optical-axis top astigmatic difference, astigmatism, a curvature of field, and image surface inclinations based on change of a difference with the optical reinforcement of the image of said phase pattern corresponding to the field in which the phase of said phase pattern was.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to inspection and amendment (adjustment) of the aberration of the projection optics of the projection aligner used at the lithography process which manufactures a semiconductor device, a liquid crystal display component, etc. especially, the alignment optical system of the alignment equipment attached to this projection aligner, and the superposition measuring beam study system of the superposition measuring device for judging the alignment result further, a focal location, optical-axis gap, etc. about the alignment equipment and the projection aligner which equipped the test equipment and the inspection approach list of optical system with this test equipment.
[0002]
[Description of the Prior Art] Conventionally, in the projection aligner used at the lithography process which manufactures a semiconductor device, a liquid crystal display component, etc., the pattern formed in the mask is imprinted through projection optics on the wafer which is a photosensitive substrate. Under the present circumstances, alignment (alignment) of the projection image of the mask pattern formed through projection optics to the already formed pattern on a wafer is carried out with the alignment equipment attached to the projection aligner, and superposition exposure is performed. Furthermore, the quality of the alignment result by alignment equipment is judged with inside installation or an external ****** superposition measuring device to a projection aligner.
[0003] If aberration remains in projection optics in this case, the projection image of a mask pattern cannot carry out image formation correctly, but the imprint pattern which has distortion on a wafer will be formed. Moreover, if aberration remains, for example in the alignment optical system of alignment equipment, exact alignment of a mask and a wafer cannot be performed and highly precise superposition exposure cannot be performed. Furthermore, with the superposition measuring beam study system of a superposition measuring device, if there is residual aberration, for example, highly precise superposition measurement cannot be performed, either.
[0004] Thus, it can begin the projection optics of a projection aligner, the alignment optical system of alignment equipment, and by setting the superposition measuring beam study system of a superposition measuring device etc. as the condition near ideal optical system as much as possible further, and equipment engine performance, such as a projection aligner, alignment equipment, and a superposition measuring device, can fully be demonstrated. The aberration of such optical system, a focal location, optical-axis gap, etc. are inspected correctly and simply, and it is more important recent years still to respond to an inspection result, and to amend or adjust to a precision.
[0005] Then, these people have proposed the projection optics of a projection aligner, the alignment optical system of alignment equipment, and the still more suitable test equipment for inspection of the superposition measuring beam study system of a superposition measuring device etc. in JP,9-49781,A. In this test equipment, comatic aberration, spherical aberration, and flux of light KERARE (the flux of light should be interrupted) are mainly correctly inspected based on this asymmetric change paying attention to an asymmetric change of the image produced when the image of a phase pattern is made to defocus gradually for example.
[0006]
[Problem(s) to be Solved by the Invention] However, in the test equipment indicated by JP,9-49781,A, many of other aberration except comatic aberration or spherical aberration was not able to be inspected correctly (often

[repeatability]) and simply.
[0007] This invention is made in view of the above-mentioned technical problem, and aims at offering the test equipment and the inspection approach of inspecting correctly and simply various aberration of optical system, a focal location, optical-axis gap, etc. Moreover, it aims at offering the projection aligner, the alignment equipment, and the superposition measuring device which can demonstrate sufficient equipment engine performance by being based on the detection result by the test equipment of this invention, and amending or adjusting the aberration of optical system, a focal location, optical-axis gap, etc.
[0008]
[Means for Solving the Problem] In order to solve said technical problem, in the 1st invention of this invention In the test equipment which inspects the optical system which has the image formation optical system for condensing the flux of light from the illumination-light study system and said phase pattern for irradiating the illumination light to a phase pattern, and carrying out image formation of the image of said phase pattern to it The image detection means for detecting the image of said phase pattern formed through said optical system, The defocusing means for making the image of said phase pattern detected in said image detection means defocus, In said image detection means, it is based on an asymmetric change of the image corresponding to the edge of each of said phase pattern detected in the state of defocusing. The test equipment characterized by having the inspection means for inspecting the inclination of the chief ray of said illumination light to the normal of the forming face of flux of light KERARE in the comatic aberration of said optical system and said optical system and said phase pattern is offered.
[0009] In the test equipment concerning the 1st invention said inspection means The asymmetry of the image corresponding to the edge of said phase pattern detected in the state of one or more defocusing in said image detection means, It is based on the asymmetry of the image corresponding to the edge of said phase pattern which detected said phase pattern or said image detection means in the state of one or more defocusing in said image detection means in the condition of having made it rotating 180 degrees, to the surroundings based on [the] detection. It is desirable to amend the asymmetric detection error of the image resulting from said phase pattern or said image detection means, and to inspect said optical system.
[0010] Moreover, it sets to the test equipment which inspects the optical system which has the image formation optical system for condensing the flux of light from the illumination-light study system and said phase pattern for irradiating the illumination light to a phase pattern, and carrying out image formation of the image of said phase pattern to it in the 2nd invention of this invention. The image detection means for detecting the image of said phase pattern formed through said optical system, It has a defocusing means for making the image of said phase pattern detected in said image detection means defocus. Said phase pattern The 1st phase pattern which repeats a periodic phase change along the detection direction of said image detection means, It has the 2nd phase pattern with which at least that [this / 1st] has different phase amplitude distribution from a phase pattern, and repeats a periodic phase change along the detection direction of said image detection means. The optical reinforcement of the image of said 1st phase pattern corresponding to the field to which the phase of said 1st phase pattern went, The 1st defocusing location where the optical reinforcement of the image of said 1st phase pattern corresponding to the field in which the phase of said 1st phase pattern was turns into optical predetermined reinforcement, respectively, The optical reinforcement of the image of said 2nd phase pattern corresponding to the field to which the phase of said 2nd phase pattern went, It is based on the 2nd defocusing location where the optical reinforcement of the image of said 2nd phase pattern corresponding to the field in which the phase of said 2nd phase pattern was turns into optical predetermined reinforcement, respectively. The test equipment characterized by having further the inspection means for inspecting the spherical aberration of said optical system is offered.
[0011] Furthermore, it sets to the test equipment which inspects the optical system which has the image formation optical system for condensing the flux of light from the illumination-light study system and said phase pattern for irradiating the illumination light to a phase pattern, and carrying out image formation of the image of said phase pattern to it in the 3rd invention of this invention. The image detection means for detecting the image of said phase pattern formed through said optical system, It has a defocusing means for making the image of said phase pattern detected in said image detection means defocus. In said illumination-light study system The lighting opening modification means for changing the amplitude distribution of said illumination light which passes a lighting aperture diaphragm is established. Said phase pattern It is the phase pattern which

repeats a periodic phase change along the detection direction of said image detection means. The optical reinforcement of the image of said phase pattern corresponding to the field to which the phase of said phase pattern illuminated under the 1st lighting conditions set up with said lighting opening modification means went, The 1st defocusing location where the optical reinforcement of the image of said phase pattern corresponding to the field in which the phase of said phase pattern was turns into optical predetermined reinforcement, respectively, The optical reinforcement of the image of said phase pattern corresponding to the field to which the phase of said phase pattern illuminated under the 2nd lighting conditions set up with said lighting opening modification means went, The test equipment characterized by having further the inspection means for inspecting the spherical aberration of said optical system based on the 2nd defocusing location where the optical reinforcement of the image of said phase pattern corresponding to the field in which the phase of said phase pattern was turns into optical predetermined reinforcement, respectively is offered.

[0012] Moreover, it sets to the test equipment which inspects the optical system which has the image formation optical system for condensing the flux of light from the illumination-light study system and said phase pattern for irradiating the illumination light to a phase pattern, and carrying out image formation of the image of said phase pattern to it in the 4th invention of this invention. The image detection means for detecting the image of said phase pattern formed through said optical system, It has a defocusing means for making the image of said phase pattern detected in said image detection means defocus. Said phase pattern The optical reinforcement of the image of said phase pattern corresponding to the field to which it is the phase pattern which repeats a periodic phase change along the detection direction of said image detection means, and the phase of said phase pattern in each defocusing condition went, It is based on change of a difference with the optical reinforcement of the image of said phase pattern corresponding to the field in which the phase of said phase pattern was. The test equipment characterized by having further the inspection means for inspecting at least one of the focal location of said optical system, the optical-axis top astigmatic difference, astigmatism, a curvature of field, and image surface inclinations is offered.

[0013] In addition, it sets to the test equipment concerning the desirable mode of the 1st invention thru/or the 4th invention, and each invention. It has at least one side of the image formation flux of light wavelength selection means for choosing the wavelength of the image formation flux of light from the lighting wavelength selection means and said phase pattern for choosing the wavelength of said illumination light which irradiates said phase pattern. It is desirable to inspect said optical system about the light of the wavelength chosen by said lighting wavelength selection means or said image formation flux of light wavelength selection means. Moreover, in order to inspect said optical system about the light of the selected wavelength, as for said phase pattern, it is desirable to have two or more phase patterns which have a different spectral reflectance or different spectral transmittance.

[0014] Moreover, as for said phase pattern, it is desirable that the duty ratio which repeats a periodic phase change along the detection direction of said image detection means is the phase pattern of 1 to 1. Moreover, the amount phi of phase changes of transparency of said phase pattern or reflective amplitude phase distribution is phi=pi (2n-1)/2 to the main wavelength of the flux of light detected with said image detection means. (n is the natural number)
It is desirable to satisfy ******.

[0015] Moreover, as for said defocusing means, it is desirable to move at least one of said phase pattern, said whole optical system or a part, and said image detection means in accordance with the optical axis of said optical system. Moreover, as for said defocusing means, it is desirable to specify the defocusing range of the image of said phase pattern detected with said image detection means centering on the defocusing location where the optical reinforcement of the image of said phase pattern corresponding to the field to which the phase of said phase pattern went, and the optical reinforcement of the image of said phase pattern corresponding to the field in which the phase of said phase pattern was become equal.

[0016] moreover, in the 5th invention of this invention The illumination-light study system for irradiating the illumination light at the alignment mark which consists of a phase pattern prepared on the photosensitive substrate with which the image of the alignment mark which consists of a phase pattern prepared on the mask with which the imprint pattern was formed, or said imprint pattern is imprinted, It has the alignment optical system which consists of image formation optical system for condensing the flux of light from said alignment mark, and carrying out image formation of the image of said alignment mark. In the alignment equipment for

performing positioning of said mask or said photosensitive substrate It has test equipment applied to the desirable mode of the 1st invention thru/or the 4th invention, and each invention in order to inspect said alignment optical system. The aberration amendment means for amending the aberration of said image formation optical system based on the inspection information on said alignment optical system by said test equipment, The focus justification means for adjusting the focus location of said image formation optical system based on said inspection information, The image formation aperture-diaphragm justification means for carrying out the relative displacement of the location of the image formation aperture diaphragm of said image formation optical system to an optical axis, in order to amend flux of light KERARE of said image formation optical system based on said inspection information, In order to amend the inclination of the chief ray of said illumination light to the normal of the body side of said image formation optical system The alignment equipment characterized by having further at least one of the lighting aperture-diaphragm justification means to which the relative displacement of the location of the lighting aperture diaphragm of said illumination-light study system is carried out to an optical axis is offered. Moreover, according to another viewpoint of this invention, in the aligner which exposes the imprint pattern formed on the mask on a photosensitive substrate, in order to perform positioning of said mask or said photosensitive substrate, it is desirable to have alignment equipment concerning the 5th invention.

[0017] Moreover, the illumination-light study system for irradiating the illumination light at the 1st pattern and the 2nd pattern which were formed on the substrate according to another viewpoint of this invention, It has the superposition measuring beam study system which consists of image formation optical system for condensing the flux of light from said 1st pattern and said 2nd pattern, and carrying out image formation of the image of said 1st pattern, and the image of said 2nd pattern. In the superposition measuring device which measures the relative-position gap with said 1st pattern and said 2nd pattern It has test equipment applied to the desirable mode of the 1st invention thru/or the 4th invention, and each invention in order to inspect said superposition measuring beam study system. The aberration amendment means for amending the aberration of said image formation optical system based on the inspection information on said alignment optical system by said test equipment, The focus justification means for adjusting the focus location of said image formation optical system based on said inspection information, The image formation aperture-diaphragm justification means for carrying out the relative displacement of the location of the image formation aperture diaphragm of said image formation optical system to an optical axis, in order to amend flux of light KERARE of said image formation optical system based on said inspection information, In order to amend the inclination of the chief ray of said illumination light to the normal of the body side of said image formation optical system, it is desirable to have further at least one of the lighting aperture-diaphragm justification means to which the relative displacement of the location of the lighting aperture diaphragm of said illumination-light study system is carried out to an optical axis.

[0018] Moreover, according to another viewpoint of this invention, in the aligner which exposes the imprint pattern formed on the mask on a photosensitive substrate, it is desirable to have the above-mentioned superposition measuring device, in order to measure the relative-position gap with the 1st pattern and the 2nd pattern which were formed on said photosensitive substrate, and to perform positioning amendment of said mask or said photosensitive substrate based on the relative-position gap information by said superposition measuring device.

[0019] Moreover, it sets to the projection aligner which equipped the mask with which the imprint pattern was formed with the illumination-light study system for irradiating the illumination light, and the projection optics for forming the image of said imprint pattern on a photosensitive substrate in the 6th invention of this invention. It has test equipment applied to the desirable mode of the 1st invention thru/or the 4th invention, and each invention in order to inspect said illumination-light study system and said projection optics. The aberration amendment means for amending the aberration of said projection optics based on the inspection information on said illumination-light study system by said test equipment, and said projection optics, The focus justification means for adjusting the focus location of said projection optics based on said inspection information, The image formation aperture-diaphragm justification means for carrying out the relative displacement of the location of the image formation aperture diaphragm of said projection optics to an optical axis, in order to amend flux of light KERARE of said projection optics based on said inspection information, In order to amend the inclination of the chief ray of said illumination light to the normal of the body side of said projection optics The projection

aligner characterized by having further at least one of the lighting aperture-diaphragm justification means to which the relative displacement of the location of the lighting aperture diaphragm of said illumination-light study system is carried out to an optical axis is offered.
[0020] Moreover, according to the 7th invention of this invention, it sets to the approach of inspecting optical system including the image formation optical system which forms the image of a predetermined phase pattern. Irradiate the illumination light at said phase pattern, and the image of said phase pattern is detected in two or more different defocusing locations in the direction of an optical axis of said image formation optical system. It is based on an asymmetric change of the image corresponding to the edge of said phase pattern detected in said two or more defocusing locations. The inspection approach of the optical system characterized by inspecting the inclination of the chief ray of said illumination light to the normal of the forming face of flux of light KERARE in the comatic aberration of said optical system and said optical system and said phase pattern is offered.
[0021] Moreover, according to the 8th invention of this invention, it sets to the approach of inspecting the optical system which includes the illumination-light study system for irradiating the illumination light, and the image formation optical system which forms the image of said phase pattern in a phase pattern. The 1st phase pattern with which said phase pattern repeats a periodic phase change along the predetermined direction, Have the phase amplitude distribution in which at least that [this / 1st] differs from a phase pattern, and it has the 2nd phase pattern which repeats a periodic phase change along said predetermined direction. The illumination light is irradiated through said illumination-light study system at said phase pattern. The image of said phase pattern The optical reinforcement of the image of said 1st phase pattern corresponding to the field to which it detected using the image detector which has the detection direction which met in said predetermined direction, and the phase of said 1st phase pattern went, The 1st defocusing location where the optical reinforcement of the image of said 1st phase pattern corresponding to the field in which the phase of said 1st phase pattern was turns into optical predetermined reinforcement, respectively, The optical reinforcement of the image of said 2nd phase pattern corresponding to the field to which the phase of said 2nd phase pattern went, Based on the 2nd defocusing location where the optical reinforcement of the image of said 2nd phase pattern corresponding to the field in which the phase of said 2nd phase pattern was turns into optical predetermined reinforcement, respectively, the inspection approach of the optical system characterized by inspecting the spherical aberration of said optical system is offered.
[0022] According to the desirable mode of the 8th invention, in addition, said illumination-light study system In case it is constituted possible [modification of the amplitude distribution of said illumination light which passes a lighting aperture diaphragm] and said 1st defocusing location is detected In case the amplitude distribution of said illumination light in said lighting aperture diaphragm is set as the 1st amplitude distribution and said 2nd defocusing location is detected, the amplitude distribution of said illumination light in said lighting aperture diaphragm is set as the 2nd different amplitude distribution from said 1st amplitude distribution.
[0023] Moreover, according to the 9th invention of this invention, it sets to the approach of inspecting optical system including the image formation optical system which forms the image of a predetermined phase pattern. Irradiate the illumination light at said phase pattern, and the image of said phase pattern is detected in two or more defocusing locations which are different in the direction of an optical axis of said image formation optical system using the image detector which has the predetermined detection direction. Said phase pattern is a phase pattern which repeats a periodic phase change along the detection direction of said image detector. The optical reinforcement of the image of said phase pattern corresponding to the field to which the phase of said phase pattern in said two or more defocusing locations went, It is based on change of a difference with the optical reinforcement of the image of said phase pattern corresponding to the field in which the phase of said phase pattern was. The inspection approach of the focal location of said optical system, the optical-axis top astigmatic difference, astigmatism, a curvature of field, and the optical system characterized by inspecting at least one of image surface inclinations is offered.
[0024]
[Embodiment of the Invention] By the test equipment and the inspection approach of this invention, in addition to flux of light KERARE in the comatic aberration of a test optical system, and a test optical system, based on change of the image corresponding to the edge of each phase pattern detected in the state of defocusing of the asymmetric index beta, it can inspect easily [repeatability is good and] and quickly so that it may explain with reference to drawing 3 and drawing 4 in the below-mentioned example, the inclination, i.e., lighting TERESEN,

of a chief ray of the illumination light to the normal of the forming face of a phase pattern. Specifically based on the fixed offset value B of the index beta independent of the amount Z of defocusing, it can calculate, the amount of inclinations of lighting TERESEN, i.e., amount, of a chief ray of the illumination light. Moreover, the amount of comatic aberration can be calculated based on slope-of-a-line C showing the index beta which changes almost in linearity depending on the amount Z of defocusing. Furthermore, based on the amount D of bending of the polygonal line showing the index beta which changes the shape of the polygonal line, and in the shape of a bay curve depending on the amount Z of defocusing, or a curve line, the amount of KERARE of the flux of light can be calculated.
[0025] In this case, based on two asymmetric indexes beta1 and beta2 of having detected the phase pattern in the two condition rotated 180 degrees to the surroundings based on [that] detection (based, for example on that arithmetic average value), the detection error of the asymmetric index beta of the image resulting from a phase pattern can be amended. Moreover, based on two asymmetric indexes beta1 and beta2 detected where [two] an image detection means like CCD is rotated 180 degrees to the surroundings based on [the] detection (based, for example on the arithmetic average value), the detection error of the asymmetric index beta of the image resulting from a phase pattern can also be amended.
[0026] Moreover, by the test equipment and the inspection approach of this invention, the spherical aberration of a test optical system can be inspected easily [repeatability is good and] and quickly using the 1st phase pattern and the 2nd phase pattern with which phase amplitude distribution (pitch) differs so that it may explain with reference to drawing 7 in the below-mentioned example. Specifically The field to which the phase of the 1st phase pattern went The 1st (it becomes index alpha= 0) defocusing location Z1 the optical reinforcement of the image corresponding to (for example, the heights of a reflective mold irregularity pattern) and whose optical reinforcement of the image corresponding to the field (for example, crevice of a reflective mold irregularity pattern) in which the phase of the 1st phase pattern was correspond, It is based on the 2nd (it becomes index alpha= 0) defocusing location Z2 the optical reinforcement of the image corresponding to the field to which the phase of the 2nd phase pattern went, and whose optical reinforcement of the image corresponding to the field in which the phase of the 2nd phase pattern was correspond. The magnitude and the amendment condition of spherical aberration of a test optical system can be searched for.
[0027] Furthermore, by the test equipment and the inspection approach of this invention, the spherical aberration of a test optical system can be inspected easily [repeatability is good and] and quickly using the same phase pattern to two different lighting conditions so that it may explain with reference to drawing 8 in the below-mentioned example. The 1st (it becomes index alpha= 0) defocusing location Z1 the optical reinforcement of the image corresponding to the field to which the phase of the phase pattern illuminated by the 1st lighting sigma value specifically went, and whose optical reinforcement of the image corresponding to the field in which the phase of a phase pattern was correspond, It is based on the 2nd defocusing location Z2 whose optical reinforcement of the image corresponding to the field in which the phase of the optical on-the-strength phase pattern of the image corresponding to the field to which the phase of the phase pattern illuminated by the 2nd lighting sigma value went was corresponds. The magnitude and the amendment condition of spherical aberration of a test optical system can be searched for.
[0028] moreover, by the test equipment and the inspection approach of this invention It is based on change of the index alpha of the difference of the optical reinforcement of the image corresponding to the field to which the phase of the phase pattern in each defocusing condition went, and the optical reinforcement of the image corresponding to the field in which the phase of a phase pattern was so that it may explain with reference to drawing 7 and drawing 8 in the below-mentioned example. The focal location of a test optical system, Even if few [of the optical-axis top astigmatic difference, astigmatism, a curvature of field, and the image surface inclinations], one can be inspected easily [repeatability is good and] and quickly.
[0029] as mentioned above, by the test equipment and the inspection approach of this invention By measuring the asymmetry (index beta) of an image and the difference (index alpha) in the image reinforcement of the concave heights of a phase pattern corresponding to the edge of a phase pattern in each defocusing condition In addition to the inclination (lighting TERESEN) of the comatic aberration of optical system, flux of light KERARE, and the illumination light, spherical aberration, a focal location, the optical-axis top astigmatic difference, astigmatism, a curvature of field, and an image surface inclination can be inspected easily [repeatability is good and] and quickly. And based on the inspection information on the detected optical

system, the optical system concerned can be brought close to ideal optical system infinite by performing amendment about the aberration and the focus location of optical system and adjustment, justification about a lighting aperture diaphragm or an image formation aperture diaphragm, etc. efficiently and proper.
[0030] Therefore, by building the test equipment of this invention into a projection aligner, alignment equipment, a superposition measuring device, etc. While inspecting easily [repeatability is good and] and quickly the illumination-light study system and projection optics of a projection aligner, the alignment optical system of alignment equipment, and the superposition measuring beam study system of a superposition measuring device Sufficient equipment engine performance can be demonstrated by being based on the detection result by test equipment, and amending or adjusting the aberration of optical system, a focal location, optical-axis gap, etc. With alignment equipment, the location detection error resulting from alignment optical system decreases, and, specifically, the measurement error resulting from a superposition measuring beam study system decreases with a superposition measuring device. Moreover, in a projection aligner, since the aberration of projection optics is amended good and the focal location, optical-axis gap, etc. are adjusted good, the pattern imprint engine performance improves and it becomes possible to perform superposition projection exposure with a high precision.
[0031] Hereafter, the example of this invention is explained based on an accompanying drawing. Drawing 1 is drawing showing roughly the configuration of the projection aligner equipped with the test equipment concerning the 1st example of this invention. In addition, in the 1st example, the alignment optical system (image formation optical system and illumination-light study system) of the alignment equipment of the off axis method attached to the projection aligner is inspected. In drawing 1 , the Y-axis is set up in the direction parallel to the space of drawing 1 in parallel to the optical axis of the projection optics PL of a projection aligner in the flat surface where the Z-axis is perpendicular to an optical axis, respectively in the direction where the X-axis is perpendicular to the Z-axis and the X-axis.
[0032] The projection aligner shown in drawing 1 is equipped with the illumination-light study system for exposure for illuminating the reticle R as a mask to homogeneity with a suitable exposure light (un-illustrating). Reticle R is supported almost in parallel with XY flat surface on the reticle stage 101, and the circuit pattern which should be imprinted is formed in the pattern space PA. The light which penetrated Reticle R reaches the wafer (or glass plate) W which is a sensitization substrate through projection optics PL, and the pattern image of Reticle R is formed on Wafer W.
[0033] In addition, Wafer W is supported almost in parallel with XY flat surface on Z stage 122 through the wafer holder 121. Z stage 122 is driven in accordance with the optical axis of projection optics PL according to a stage control system 124. Z stage 122 is further supported on X-Y stage 123. Similarly X-Y stage 123 is driven two-dimensional in perpendicular XY flat surface to the optical axis of projection optics PL according to a stage control system 124.
[0034] It is necessary to carry out alignment (alignment) of pattern space PA and each exposure field on Wafer W optically in the case of projection exposure. Then, the location in the standard coordinates of the level difference mark WM for alignment, i.e., a wafer mark, formed on Wafer W is detected, and alignment is performed based on the positional information. Thus, although the location of the wafer mark WM is detected and alignment is performed, the alignment equipment of this invention is used.
[0035] The alignment equipment shown in drawing 1 is equipped with the light source 103 like a halogen lamp in order to supply the illumination light (alignment light AL). The light from the light source 103 is drawn to a predetermined location through a light guide 104 like an optical fiber. After the illumination light injected from the injection edge of a light guide 104 is restricted by the lighting aperture diaphragm 127 if needed, it serves as an illumination-light bundle which has a suitable cross-section configuration, and carries out incidence to a condenser lens 129.
[0036] Once it is condensed, incidence of the alignment light AL through a condenser lens 129 is carried out to the lighting relay lens 105 through a lighting field diaphragm (un-illustrating). After the alignment light AL which turned into parallel light through the lighting relay lens 105 penetrates the half prism 106, incidence of it is carried out to the 1st objective lens 107. The alignment light AL condensed with the 1st objective lens 107 illuminates the wafer mark WM which is an alignment mark formed on Wafer W, after being reflected by the method of drawing Nakashita in the reflector of a reflecting prism 108.
[0037] Thus, the light source 103, a light guide 104, the lighting aperture diaphragm 127, a condenser lens 129,

a lighting field diaphragm (un-illustrating), the lighting relay lens 105, the half prism 106, the 1st objective lens 107, and a reflecting prism 108 constitute the illumination-light study system for irradiating the illumination light to the wafer mark WM.
[0038] Incidence of the reflected light from the wafer mark WM to the illumination light is carried out to the half prism 106 through a reflecting prism 108 and the 1st objective lens 107. The light reflected by the method of drawing Nakagami forms the image of the wafer mark WM on the index plate 112 through the 2nd objective lens 111 by the half prism 106. Incidence of the light through the index plate 112 is carried out to XY branching half prism 115 through a relay lens system (113,114). And incidence of the light to which the light reflected by XY branching half prism 115 penetrated XY branching half prism 115 to CCD116 for the directions of Y is carried out to CCD117 for the directions of X. In addition, in the parallel optical path of a relay lens system (113,114), the image formation aperture diaphragm 130 is arranged if needed.
[0039] Thus, a reflecting prism 108, the 1st objective lens 107, the half prism 106, the 2nd objective lens 111, the index plate 112, a relay lens system (113,114), the image formation aperture diaphragm 130, and the half prism 115 constitute the image formation optical system for forming a mark image based on the reflected light from the wafer mark WM to the illumination light. Moreover, CCD116 for the directions of Y and CCD117 for the directions of X constitute the image detection means for detecting the mark image formed through image formation optical system.
[0040] In this way, a mark image is formed in the image pick-up side of CCD116 for the directions of Y, and CCD117 for the directions of X with the index pattern image of the index plate 112. The output signal from CCD116 for the directions of Y and CCD117 for the directions of X is supplied to a signal-processing system 118. Furthermore, the positional information of the wafer mark WM obtained by signal processing (wave processing) in the signal-processing system 118 is supplied to the main control system 125.
[0041] The main control system 125 outputs a stage control signal to a stage control system 124 based on the positional information of the wafer mark WM from a signal-processing system 118. A stage control system 124 drives X-Y stage 123 suitably according to a stage control signal, and performs alignment of Wafer W. In addition, the command to the lighting aperture diaphragm 127 and the command to the image formation aperture diaphragm 130 are supplied to the main control system 125 through an input means 126 like a keyboard. Based on these commands, through a drive system 128, the lighting aperture diaphragm 127 is driven or the main control system 125 drives the image formation aperture diaphragm 130 through a drive system 131. Moreover, the main control system 125 drives the 2nd objective lens 111 and a relay lens 113 based on the aberration amendment command mentioned later.
[0042] Although the wafer mark WM is formed as an alignment mark on Wafer W as mentioned above, the duty ratio to which this wafer mark WM repeats a periodic phase change along the measurement direction of CCD116 or the measurement direction of CCD117 is the phase pattern of 1 to 1. Such a phase pattern can be formed in an exact configuration in a desired precision by carrying out etching processing of the silicon wafer which carried out exposure processing with the projection aligner. In addition, in order to obtain sharp detection sensitivity in aberration measurement of the optical system mentioned later etc., it is desirable for the amount phi of phase changes of reflective amplitude phase distribution of a phase pattern to satisfy the following formulas (a) to the main wavelength of the flux of light detected by CCD 116 and 117.
Phi=pi (2n-1)/2 (n is the natural number) (a)
[0043] Drawing 2 is drawing which plotted integral signal sigmaV which integrated with the signal V according to the optical reinforcement of a phase pattern image in the non-measuring direction to the measurement direction S, and is drawing for explaining the asymmetric index beta of a phase pattern image. In the 1st example, the image of the wafer mark WM which consists of a phase pattern is formed in the image pick-up side of CCD (116,117) which is an image sensor. Therefore, in drawing 2 , integral signal sigmaV which integrated with the image pick-up signal V from an image sensor (116,117) in the non-measuring direction is plotted to the measurement direction S.
[0044] As shown in drawing 2 , integral signal sigmaV changes along the measurement direction S to every period BP (the scale factor of B:image-formation optical system, P: pitch of the phase pattern WM on a wafer). In the 1st example, in order to quantify the asymmetry of a phase pattern image, in distribution of integral signal sigmaV, the signal minimal value (signal value of the depression edge section) of the right and left in the i-th period (drawing 2 the 2nd) among drawing is set to ViL and ViR (i= 1, 2, 3 ...), respectively. Moreover, except

for a part for the both ends of integral signal sigmaV, it sets to the whole field covering each period, and is Vmax about the maximum and the minimum value of a signal, respectively. And Vmin It carries out.
[0045] And it asks for the asymmetric index beta of a phase pattern image based on the following formula (1).
Beta=sigma {ViL-ViR/(Vmax-Vmin)} /n (1)
Here, n is periodicity and sigma is a summation symbol to i=1-n.
[0046] Drawing 3 and drawing 4 are drawings showing change of the asymmetric index beta of the phase pattern image in each defocusing condition that a stage control system 124 is acquired by driving Z stage 122 suitably based on the command of the main control system 125, and the relation between comatic aberration, an optical-axis gap, etc. Index beta is 0, without being dependent on the amount Z of defocusing in the ideal optical adjustment condition that there is no residual aberration in a test optical system (in this case, image formation optical system and an illumination-light study system), and an optical-axis gap does not exist, either, as a straight line L1 shows drawing 3 (a).
[0047] Moreover, when the chief ray of the illumination light which irradiates a body side (namely, wafer side) in a test optical system (in this case, illumination-light study system) inclines to the normal of a body side (henceforth "the case where there is lighting TERESEN"), as for Index beta, the fixed offset value B is taken, without being dependent on the amount Z of defocusing, as a straight line L2 shows drawing 3 R> 3 (b). This offset value B is mostly, are proportional to the amount of inclinations of lighting TERESEN, i.e., amount, of a chief ray of the illumination light to the normal of a body side.
[0048] Furthermore, when comatic aberration exists in a test optical system (in this case, image formation optical system), as a straight line L3 shows drawing 4 (a), as for Index beta, almost linearity-change is shown depending on the amount Z of defocusing. And inclination C of this straight line L3 is proportional to the amount of comatic aberration mostly. Moreover, when KERARE of the image formation flux of light exists in a test optical system (it is image formation optical system also in this case), as drawing 4 (b) is shown, Index beta shows fluctuation as shown according to change of the amount Z of defocusing with the polygonal line (or curved curve as shown with a broken line) L4. And the amount D of bending of this polygonal line or the curve line L4 is proportional to the amount of KERARE of the image formation flux of light mostly.
[0049] In this way, flux of light KERARE can be calculated [lighting TERESEN] for comatic aberration from the amount D of bending with the value C of an inclination, respectively by the relation of the Index beta and the amount Z of defocusing which are made to defocus a phase pattern image and are obtained to the offset value B. Moreover, in above-mentioned explanation, the field which detects a phase pattern image may be limited to the range of desired. That is, in a formula (1), the range of i= 1 - n may be limited. Thus, by limiting, lighting TERESEN of the test optical system in the location of the arbitration on a body side, flux of light KERARE, and comatic aberration can be inspected. Furthermore, it becomes possible by conducting above-mentioned inspection to each point of a visual field to distinguish the eccentric comatic aberration and image quantity comatic aberration for example, within a detection visual field. Moreover, it is the same also about lighting TERESEN or flux of light KERARE.
[0050] Drawing 5 is drawing which plotted integral signal sigmaV which integrated with the signal V according to the optical reinforcement of a phase pattern image in the non-measuring direction to the measurement direction S, and is drawing for explaining the index alpha which quantified the difference between the image reinforcement of the phase pattern image corresponding to the crevice of a phase pattern, and the image reinforcement of the phase pattern image corresponding to heights. Thus, although drawing 5 is drawing corresponding to drawing 2 , the test optical system with which neither comatic aberration nor flux of light KERARE exists for simplification is assumed in instantiation.
[0051] As mentioned above, in the 1st example, the image of the wafer mark WM which consists of a phase pattern is formed in the image pick-up side of CCD (116,117) which is an image sensor. Therefore, in drawing 5 , integral signal sigmaV which integrated with the image pick-up signal V from an image sensor (116,117) in the non-measuring direction is plotted to the measurement direction S like drawing 2 . As shown in drawing 5 , integral signal sigmaV changes along the measurement direction S to every period BP (B: [of image formation optical system / scale-factor]. : pitch of the phase pattern WM on a wafer). In the 1st example, in order to quantify the difference between the image reinforcement of the phase pattern image corresponding to the crevice of a phase pattern, and the image reinforcement of the phase pattern image corresponding to heights In distribution of integral signal sigmaV, integral signal sigmaV corresponding to the crevice of the i-th phase

pattern is set to Vio (i= 1, 2, 3 ...), and integral signal sigmaV corresponding to the heights of the i-th phase pattern is set to Vit (i= 1, 2, 3 ...).
[0052] And it asks for the index alpha of the difference between the image reinforcement of the phase pattern image corresponding to the crevice and heights of a phase pattern by the following formula (2), respectively.
Alpha=sigma {Vit-Vio/(Vit+Vio)} /(2n) (2)
Here, n is periodicity and sigma is a summation symbol to i=1-n.
[0053] Drawing 6 is drawing showing the relation of the change and spherical aberration of the index alpha of the difference between the image reinforcement of the phase pattern image corresponding to the crevice and heights of a phase pattern in each defocusing condition that a stage control system 124 is acquired by driving Z stage 122 suitably based on the command of the main control system 125, respectively. In addition, in drawing 6 and other related drawings (drawing 7 and drawing 8), Z= 0 supports the paraxial image surface location of a test optical system. Moreover, alpha= 0 supports the condition that the image reinforcement of the phase pattern image corresponding to the crevice of a phase pattern and the image reinforcement of the phase pattern image corresponding to heights become equal. When spherical aberration does not exist in a test optical system (in this case, image formation optical system), Index alpha shows change which was mostly in direct proportion according to the value of the amount Z of defocusing. Namely, in the straight line L1 which shows change of Index alpha, it is set to Z= 0 at the time of alpha= 0.
[0054] On the other hand, when the spherical aberration of amendment over exists in a test optical system, in the straight lines L2 and L3 which show change of Index alpha, the value of Z at the time of alpha= 0 serves as negative. Moreover, the absolute value of Z at the time of alpha= 0 becomes large according to the magnitude of the amount of spherical aberration. namely, amendment -- the direction of the absolute value of Z in case the straight line L2 which shows change of the index alpha in case exaggerated spherical aberration exists comparatively greatly crosses the Z-axis (axis of alpha= 0) -- amendment -- it becomes larger than the absolute value of Z in case the straight line L3 which shows change of the index alpha in case exaggerated spherical aberration exists comparatively small crosses the Z-axis. Thus, when the spherical aberration of amendment over exists, the defocusing location where the image reinforcement of the phase pattern image corresponding to the crevice of a phase pattern and the image reinforcement of the phase pattern image corresponding to heights become equal serves as an inclination which separates from the paraxial image surface location of Z= 0 to a negative direction according to the magnitude of the amount of spherical aberration.
[0055] Moreover, when the spherical aberration of an amendment undershirt exists in a test optical system, in the straight lines L4 and L5 which show change of Index alpha, the value of Z at the time of alpha= 0 serves as forward. Moreover, the value of Z at the time of alpha= 0 becomes large according to the magnitude of the amount of spherical aberration. That is, it becomes larger than the value of Z in case the straight line L5 the direction of the value of Z in case the straight line L4 which shows change of the index alpha in case the spherical aberration of an amendment undershirt exists comparatively greatly crosses the Z-axis (axis of alpha= 0) indicates change of the index alpha in case the spherical aberration of an amendment undershirt exists comparatively small to be crosses the Z-axis. Thus, when the spherical aberration of an amendment undershirt exists, the defocusing location where the image reinforcement of the phase pattern image corresponding to the crevice of a phase pattern and the image reinforcement of the phase pattern image corresponding to heights become equal serves as an inclination which separates from the paraxial image surface location of Z= 0 to a positive direction according to the magnitude of the amount of spherical aberration.
[0056] Drawing 7 is drawing showing the relation of the amount Z of defocusing and Index alpha about two kinds of phase patterns with which periods differ, and (a) shows the case where, as for (b), spherical aberration does not exist the case where spherical aberration exists in a test optical system, respectively. Whenever [angle-of-diffraction / of the diffracted light which the phase pattern with a small period produces from a pattern rather than the case of the large phase pattern of a period] is large, and it is easier to be influenced of spherical aberration. Therefore, when spherical aberration exists in a test optical system, the straight line L1 from which the direction of the location Z2 where the straight line L2 obtained to a phase pattern with a small period intersects the Z-axis is obtained to a phase pattern with a large period separates from the paraxial image surface location of Z= 0 rather than the location Z1 which intersects the Z-axis.
[0057] On the other hand, when spherical aberration does not exist in a test optical system, the location Z2 where the straight line L2 obtained to a phase pattern with a small period intersects the Z-axis, and the location

Z1 where the straight line L1 from which it is obtained to a phase pattern with a large period intersects the Z-axis are in agreement with the paraxial image surface location of Z= 0. As mentioned above, it turns out that the difference (Z2-Z1) of Z2 and Z1 is proportional to the magnitude of the spherical aberration which remains in a test optical system, and the sign of the positive/negative of difference (Z2-Z1) deals with the amendment over and amendment undershirt of spherical aberration. If it puts in another way, based on above-mentioned difference (Z2-Z1), the magnitude and its amendment condition of spherical aberration of a test optical system can be searched for from the relation of the Index alpha and the amount Z of defocusing which are obtained when a phase pattern image is made to defocus using two kinds of phase patterns with which periods differ.
[0058] Drawing 8 is drawing showing the relation of the amount Z of defocusing and Index alpha about the same phase pattern when illuminating by two kinds of lighting sigma values, and (a) shows the case where, as for (b), spherical aberration does not exist the case where spherical aberration exists in a test optical system, respectively. Here, the ratio [as opposed to image formation numerical aperture in Lighting sigma] of lighting numerical aperture is said. By the case where the direction of lighting with a comparatively large lighting sigma value is lighting with a comparatively small lighting sigma value, as for the image formation flux of light from a phase pattern, it is easier to be influenced of spherical aberration. therefore -- a test optical system -- setting -- spherical aberration -- existing -- a case -- lighting -- a sigma value -- being large -- a case -- obtaining -- having -- a straight line -- L -- two -- ' -- the Z-axis -- crossing -- a location -- Z -- two -- the direction -- lighting -- a sigma value -- being small -- a case -- obtaining -- having -- a straight line -- L -- one -- ' -- the Z-axis -- crossing -- a location -- Z -- one -- from the paraxial image surface location of Z= 0 -- separating .
[0059] on the other hand -- a test optical system -- setting -- spherical aberration -- not existing -- a case -- lighting -- a sigma value -- being large -- a case -- obtaining -- having -- a straight line -- L -- two -- ' -- the Z-axis -- crossing -- a location -- Z -- two -- lighting -- a sigma value -- being small -- a case -- obtaining -- having -- a straight line -- L -- one -- ' -- the Z-axis -- crossing -- a location -- Z -- one -- the paraxial image surface location of Z= 0 -- being in agreement . As mentioned above, it turns out that the difference (Z2-Z1) of Z2 and Z1 is proportional to the magnitude of the spherical aberration which remains in a test optical system like the case where two kinds of phase patterns with which periods differ are used when illuminating the same phase pattern by two kinds of lighting sigma values, and the sign of the positive/negative of difference (Z2-Z1) deals with the amendment over and amendment undershirt of spherical aberration. If it puts in another way, based on above-mentioned difference (Z2-Z1), the magnitude and its amendment condition of spherical aberration of a test optical system can be searched for from the relation of the Index alpha and the amount Z of defocusing which are obtained when the same phase pattern is illuminated by two kinds of lighting sigma values and a phase pattern image is made to defocus.
[0060] Moreover, as it understands easily by explanation of drawing 7 and drawing 8 , the defocusing location which in the case of which becomes with an index alpha= 0 at it when there is no spherical aberration in a test optical system is a Z location of the paraxial image surface. Moreover, when spherical aberration is in a test optical system, based on the 2nd defocusing location Z2 which serves as an index alpha= 0 to the phase pattern (the 2nd lighting sigma) of the 1st defocusing location Z1 and the 2nd period which serves as an index alpha= 0 to the phase pattern (the 1st lighting sigma) of the 1st period, a paraxial image surface location and the optical-axis top astigmatic difference can be searched for.
[0061] Moreover, in above-mentioned explanation, the field which detects a phase pattern image may be limited to the range of desired. That is, in a formula (2), the range of i= 1 - n may be limited. Thus, by limiting, it becomes possible to inspect the astigmatism, curvature of field, and image surface inclination other than the paraxial image surface location of a test optical system, or the optical-axis top astigmatic difference (for above-mentioned inspection to be conducted to each point of a visual field).
[0062] moreover, choose the wavelength of the illumination light which inserts a light filter etc. into the optical path of an illumination-light study system, and irradiates a phase pattern, or Two or more phase patterns with which spectral reflectances (the case of a transparency mold spectral transmittance) differ are prepared. Choose the wavelength of the reflected light (the case of a transparency mold transmitted light) from a phase pattern, or By inserting a light filter and choosing the wavelength of the image formation flux of light from a phase pattern into the optical path of image formation optical system, it becomes possible to inspect a test optical system about desired wavelength. Consequently, various kinds of already explained monochromatic aberration is inspected for every wavelength, and also axial overtone aberration and the chromatic aberration outside a shaft

can also be inspected.
[0063] In the above explanation, in case the asymmetric index beta of a phase pattern image is quantified, the right-and-left minimal value ViL and ViR of the signal for a round term is used. However, the asymmetric index beta of a phase pattern image can also be quantified using the width of face of the depression edge section of the right and left in the signal for a round term as indicated on the Japanese-Patent-Application-No. No. 20325 [seven to] specifications (JP,8-213306,A) by application of these people.
[0064] Processing which is different from this example also about the index alpha of the difference between the image reinforcement of the phase pattern image corresponding to the heights and the crevice of a phase pattern, respectively is possible further again. Drawing 9 is drawing showing signs that an angle arises in the image intensity distribution of a phase pattern image in the image wave on the strength corresponding to heights and a crevice, when the image reinforcement of the phase pattern image corresponding to the heights of a phase pattern and the image reinforcement of the phase pattern image corresponding to a crevice are in agreement. In this case, in the image intensity distribution of a phase pattern image, the defocusing location which the angle produced can also be adopted as the image wave on the strength corresponding to heights and a crevice as a location Z1 or a location Z2, without asking for Index alpha directly.
[0065] Moreover, the asymmetric index beta 1 of the image corresponding to the edge of the phase pattern detected in the state of one or more defocusing in order to secure the correctness, in case it asks for Index beta, A phase pattern The asymmetric index beta 2 of the image corresponding to the edge of said phase pattern detected in the state of one or more (in namely, the condition of having rotated the phase pattern 180 degrees to the circumference of the Z-axis in this example) defocusing in the condition of having made it rotating 180 degrees to the surroundings based on [the] detection is detected, respectively. It is desirable to calculate the average betaave1 by the following formula (3).
betaave1= (beta1+beta2)/2 (3)
By using this average betaave1 as an asymmetric index beta of the phase pattern image at the time of inspecting a test optical system, the detection error by the asymmetry of the phase pattern itself can be amended.
[0066] In furthermore, the asymmetric index beta 1 of the image corresponding to the edge of the phase pattern detected in the state of one or more defocusing and the condition of having rotated the image sensor (this example CCD 116 and 117) 180 degrees to the surroundings based on [the] detection It is desirable to detect the asymmetric index beta 2 of the image corresponding to the edge of the phase pattern detected in the state of one or more defocusing, respectively, and to calculate the average betaave2 by the following formula (4).
betaave2= (beta1+beta2)/2 (4)
By using this average betaave2 as an asymmetric index beta of the phase pattern image at the time of inspecting a test optical system, the detection error by the asymmetry of the image sensor itself can be amended.
[0067] In addition, the sensibility to the amount Z of defocusing of Index beta and Index alpha defocused and obtained depends for a phase pattern image on a lighting sigma value, the pitch of a pattern, duty ratio, a taper, a level difference, etc. Therefore, it is desirable by choosing these parameters suitably to control inspection sensibility to be able to conduct optimal inspection in a real busy condition.
[0068] Moreover, it is desirable to choose the suitable range centering on Z location where Index alpha becomes 0 as defocusing range at the time of defocusing a phase pattern image. Thus, by selecting the defocusing range, the aspect of change of Index beta can be grasped correctly. Moreover, the whole test optical system besides a means to make the Z stage which carried the wafer with which the phase pattern was formed as a defocusing means drive up and down or the means, to which it is made to move in accordance with an optical axis in part, and the means to which at least one side of the image pick-up means is moved in accordance with the optical axis of a test optical system can be used.
[0069] In the above, in addition to the inclination of the comatic aberration of a test optical system, eccentric comatic aberration, flux of light KERARE, and the illumination light, by measuring the asymmetric index beta of the edge of a phase pattern image and the index alpha of the difference in the image reinforcement of the concave heights of a phase pattern explained that inspection about the light of the wavelength of the arbitration of spherical aberration, a focal location and the optical-axis top astigmatic difference, astigmatism, a curvature of field, and an image surface inclination could be conducted, defocusing a phase pattern image. Next, the approach of the justification about the approach of the amendment performed based on such inspection information (detection result) or adjustment, i.e., the amendment and adjustment about the aberration and the

focus location of a test optical system, a lighting aperture diaphragm, or an image formation aperture diaphragm is explained.
[0070] First, in order to adjust lighting TERESEN (inclination of the illumination light), the lighting aperture diaphragm 127 is justified. Specifically, the lighting aperture diaphragm 127 is suitably driven in a perpendicular direction or the advancing-side-by-side direction to an optical axis through a drive system 128. Moreover, when the injection edge of a light guide 104 serves as the lighting aperture diaphragm, a light guide 104 is suitably driven in a perpendicular direction or the advancing-side-by-side direction to an optical axis. Furthermore, a flux of light parallel displacement means like a plane-parallel plate may be established into the optical path between a light guide 104 and a condenser lens 129, or the optical path between the lighting relay lens 105 and the half prism 106. When using a plane-parallel plate as a flux of light parallel displacement means, lighting TERESEN can be adjusted by making this plane-parallel plate incline.
[0071] On the other hand, in order to adjust KERARE of the image formation flux of light, the image formation aperture diaphragm 130 is justified. Specifically, the image formation aperture diaphragm 130 is suitably driven in a perpendicular direction or the advancing-side-by-side direction to an optical axis through a drive system 131. Moreover, it is between the inside of the optical path between the half prism 106 and the 2nd objective lens 111 or a relay lens 113, and a relay lens 114, and a flux of light parallel displacement means like a plane-parallel plate may be established into the optical path by the side of a wafer rather than the image formation aperture diaphragm 130. When using a plane-parallel plate as a flux of light parallel displacement means, KERARE of the image formation flux of light can also be adjusted by making this plane-parallel plate incline.
[0072] Furthermore, in order to amend spherical aberration of image formation optical system, the 2nd objective lens 111 and a relay lens 113 are suitably driven in accordance with an optical axis. Or the spherical aberration of image formation optical system can be amended by changing spacing of the 2nd objective lens 111 and a relay lens 113. Moreover, spherical aberration is controllable also by driving a Z stage and changing spacing with the Wth page of a wafer, and the 1st objective lens 107. However, a defocused part of the image on the image pick-up side of CCD must be absorbed in this case by making CCD advance side by side suitably for the direction of an optical axis.
[0073] Moreover, the eccentric comatic aberration of image formation optical system can amend the 2nd objective lens 111, and the whole lens system of a relay lens 113 or some lenses by carrying out an eccentric drive perpendicularly to an optical axis. In addition, what is necessary is just to drive a Z stage suitably in the direction of an optical axis, in order to perform adjustment about a focus location (focal location). Moreover, what is necessary is just to move suitably either [at least] CCD of the direction of X, or CCD of the direction of Y along the direction of an optical axis, in order to amend the optical-axis top astigmatic difference.
[0074] Furthermore, usually becoming a problem by the management on the consideration and manufacture on an optical design has little aberration of image quantity comatic aberration, a curvature of field, an image surface inclination, etc. However, such aberration can also be amended if needed by changing and replacing the lens type of some lens systems of image formation optical system, or carrying out eccentricity of some lens systems. It is the same as that of such aberration also about amendment of chromatic aberration.
[0075] Drawing 10 is the perspective view showing roughly the configuration of the projection aligner equipped with the test equipment concerning the 2nd example of this invention. In addition, although the image formation optical system and the illumination-light study system of alignment equipment of an off axis method which were attached to the projection aligner are inspected in the 1st example, the projection optics and the illumination-light study system of a projection aligner are inspected in the 2nd example. Moreover, although CCD is used as an image detection means in the 1st example, the criteria member and photodetector with which the slit was formed as an image detection means are used in the 2nd example. In drawing 1010 , it is set up, respectively so that the X-axis and a Y-axis may intersect perpendicularly mutually in parallel to the optical axis AX of the projection optics PL of a projection aligner in the flat surface where the Z-axis is perpendicular to an optical axis AX.
[0076] The projection aligner of drawing 10 is equipped with the light source LP which consists of an extra-high pressure mercury lamp. The light source LP is positioned in the 1st focal location of the converging mirror (ellipse mirror) EM which has the reflector which consists of an ellipsoid of revolution. Therefore, the illumination-light bundle injected from the light source LP forms a light source image (secondary light source) in the 2nd focal location of the ellipse mirror EM.

[0077] The light from the secondary light source is a collimate lens GL and a mirror M1. After minding, it becomes the parallel flux of light and incidence is carried out to the fly eye lens floor line. The flux of light which carried out incidence to the fly eye lens floor line is divided two-dimensional by two or more lens elements which constitute the fly eye lens floor line, and forms two or more light source images (Miyoshi light source) in a backside [the fly eye lens floor line] focal location (a injection side near [namely,]).
[0078] The flux of light from two or more light source images is the mirror M2 after being restricted by the adjustable aperture diaphragm 12 arranged in the injection side of the fly eye lens floor line. It minds and incidence is carried out to a condenser lens CL. The light condensed through the condenser lens CL illuminates to homogeneity the mask 14 with which the pattern for an imprint was formed in superposition. Thus, the light source PL, the ellipse mirror EM, a collimate lens GL, a mirror M1, the fly eye lens floor line, the adjustable aperture diaphragm 12, the mirror M2, and the condenser lens CL constitute the illumination-light study system 11.
[0079] On the occasion of exposure, the flux of light which penetrated the mask 14 reaches the wafer (un-illustrating) which is a sensitization substrate through projection optics 17. In this way, the pattern image of a mask 14 is formed on a wafer. The wafer is supported at the movable Z stage 13 top along movable X-Y stage 18 and the optical-axis AX direction of projection optics 17 to the optical axis AX (parallel to a Z direction) of projection optics 17 two-dimensional in perpendicular XY flat surface. Therefore, the pattern of a mask 14 can be serially imprinted to each exposure field of a wafer by exposing moving a wafer two-dimensional.
[0080] The automatic focus system (22A, 22B) of an oblique incidence light method is prepared in the projection aligner of drawing 10 . By the automatic focus system of an oblique incidence light method, light transmission system 22A irradiates light from across toward the front face of a wafer. The light by which specular reflection was carried out on the wafer front face is received by light-receiving system 22B, and the Z direction location of a wafer is detected based on location change of the reflected light. in this way, an operation of an automatic focus system (22A, 22B) -- exposure -- facing -- a wafer front face -- the image formation side (a mask 14 and field [****]) of projection optics 17 -- about -- it can be made to do one
[0081] On the other hand, on the occasion of inspection, on X-Y stage 18, it replaces with a wafer and the criteria member PT and an electric eye 23 are installed. And the front face of the criteria member PT is positioned in a predetermined defocusing location to projection optics 17 according to an operation of an automatic focus system (22A, 22B) and Z stage 13. in this case -- first -- an automatic focus system (22A, 22B) -- using -- the front face of the criteria member PT -- the image formation side of projection optics 17 -- receiving -- about -- it is made to do one and let this location be a paraxial image surface location (Z= 0). Subsequently, when only the specified quantity Z (the amount of defocusing) drives Z stage 13 on the basis of a paraxial image surface location (Z= 0), the front face of the criteria member PT can be positioned in a predetermined defocusing location. In addition, a pattern 16 and projection optics 17 can be moved to a Z direction, and a defocusing condition can also be formed.
[0082] In each defocusing condition, the flux of light which penetrated the checking phase pattern 16 formed in the mask 14 arrives at the front face of the criteria member PT through projection optics 17. In this way, checking phase pattern image 16A of a mask 14 is formed in the front face of the criteria member PT in the state of each defocusing. Incidence of the light from phase pattern image 16A is carried out to an electric eye 23 through the slit 19 formed in the front face of the criteria member PT. The slit 19 is formed by one slit pattern. Therefore, in an electric eye 23, the electrical signal according to the optical intensity distribution of phase pattern image 16A can be acquired with the slit scan method which makes phase pattern image 16A and a slit 19 displaced relatively in the predetermined direction.
[0083] Although the criteria member PT and electric eye 23 in which the slit 19 was formed as an image detection means are used by the 2nd example to using CCD as an image detection means in the 1st example as mentioned above, the amendment and the adjustment of aberration etc. based on the detection and detection information on aberration etc. based on the optical intensity distribution of the obtained phase pattern image are the same as that of the 1st example. Namely, by measuring the asymmetric index beta of the edge of a phase pattern image, and the index alpha of the difference in the image reinforcement of the concave heights of a phase pattern, defocusing a phase pattern image like the 1st example also in the 2nd example In addition to the inclination of the comatic aberration of a test optical system (projection optics 17 and illumination-light study system 11), eccentric comatic aberration, flux of light KERARE, and the illumination light, inspection about the

light of the wavelength of the arbitration of spherical aberration, a focal location and the optical-axis top astigmatic difference, astigmatism, a curvature of field, and an image surface inclination can be conducted. Moreover, it can be based on such inspection information (detection result), and the aberration and the focus location of a test optical system, and optical-axis gap can be amended or adjusted.

[0084] For example, in the projection aligner of drawing 10 , in order to amend the spherical aberration and comatic aberration of projection optics 17, among each lens component which constitutes projection optics 17, to spherical aberration or comatic aberration, a sensitive lens is shifted to an optical axis AX (migration), or carries out a tilt (inclination). Moreover, the aberration of others of projection optics 17 can also be processed by the same view as the 1st example. On the other hand, in the projection aligner of drawing 10 , in order to adjust lighting TERESEN, flux of light KERARE, etc. proper, the adjustable aperture diaphragm 12 and the aperture diaphragm in projection optics 17 are suitably driven to an optical axis AX.

[0085] Moreover, the test equipment of this invention is applicable to a superposition measuring device as the 3rd example of this invention. A superposition measuring device is equipment which measures the relative-position gap with the 1st pattern and the 2nd pattern which were formed on inside installation or external ****, and a photosensitive substrate at the projection aligner. And the alignment optical system of the alignment equipment mentioned above and the superposition measuring beam study system of a superposition measuring device have a similar configuration optically. Therefore, like the case of alignment equipment, while inspecting the aberration of a superposition measuring beam study system etc. correctly and simply, based on the inspection information, the aberration of a superposition measuring beam study system etc. can be amended good.

[0086] In addition, in the test equipment and the inspection approach of this invention, an image pick-up method may perform asymmetric detection of a phase pattern image like the 1st example, and you may carry out by the scanning method by the slit like the 2nd example. Moreover, it does not depend for this invention on the difference in lighting like transmitted illumination or epi-illumination (reflected illumination). Moreover, it is applicable to other common equipments which have the optical system which should inspect the test equipment of this invention not only in a projection aligner, a superposition measuring device, or alignment equipment.

[0087]

[Effect of the Invention] As explained above, according to the test equipment and the inspection approach of this invention, by measuring the asymmetry (index beta) of an image and the difference (index alpha) in the image reinforcement of the concave heights of a phase pattern corresponding to the edge of a phase pattern in each defocusing condition The comatic aberration of optical system, eccentric comatic aberration, In addition to the inclination (lighting TERESEN) of flux of light KERARE and the illumination light, spherical aberration, a focal location, the optical-axis top astigmatic difference, astigmatism, a curvature of field, and an image surface inclination can be inspected easily [repeatability is good and] and quickly about the light of the wavelength of arbitration. And based on the inspection information on the detected optical system, the optical system concerned can be brought close to ideal optical system infinite by performing amendment about the aberration and the focus location of optical system and adjustment, justification about a lighting aperture diaphragm or an image formation aperture diaphragm, etc. efficiently and proper.

[0088] Therefore, by building the test equipment of this invention into a projection aligner, alignment equipment, a superposition measuring device, etc. While inspecting easily [repeatability is good and] and quickly the illumination-light study system and projection optics of a projection aligner, the alignment optical system of alignment equipment, and the superposition measuring beam study system of a superposition measuring device Sufficient equipment engine performance can be demonstrated by being based on the detection result by test equipment, and amending or adjusting the aberration of optical system, a focal location, optical-axis gap, etc. With alignment equipment, the location detection error resulting from alignment optical system decreases, and, specifically, the measurement error resulting from a superposition measuring beam study system decreases with a superposition measuring device. Moreover, in a projection aligner, since the aberration of projection optics is amended good and the focal location, optical-axis gap, etc. are adjusted good, the pattern imprint engine performance improves and it becomes possible to perform superposition projection exposure with a high precision.

[Translation done.]

* NOTICES *

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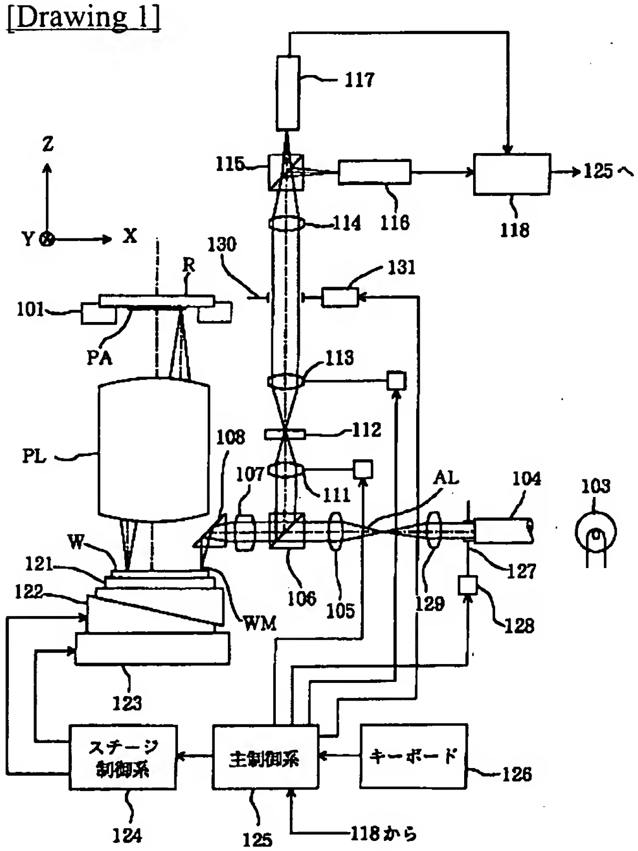
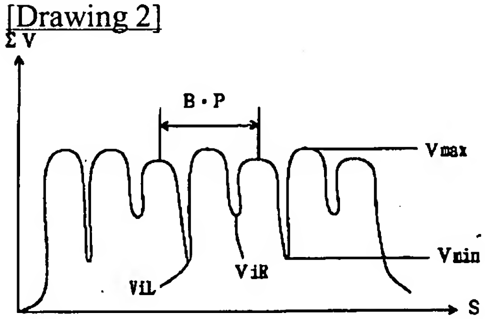
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

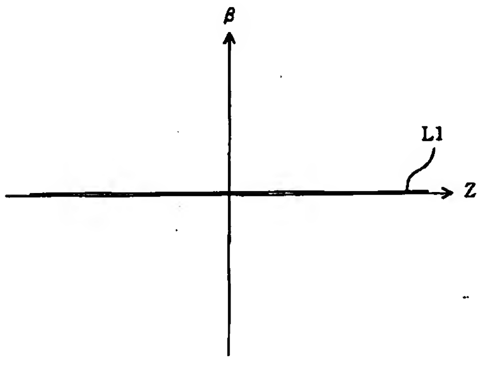
[Drawing 1]



[Drawing 2]



[Drawing 3]



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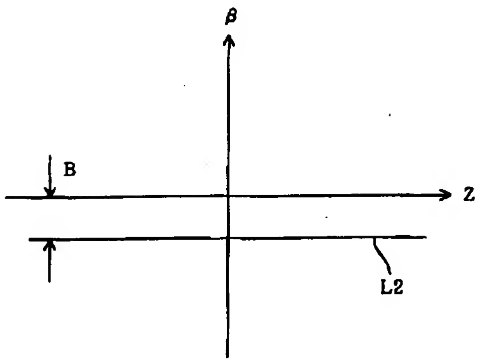

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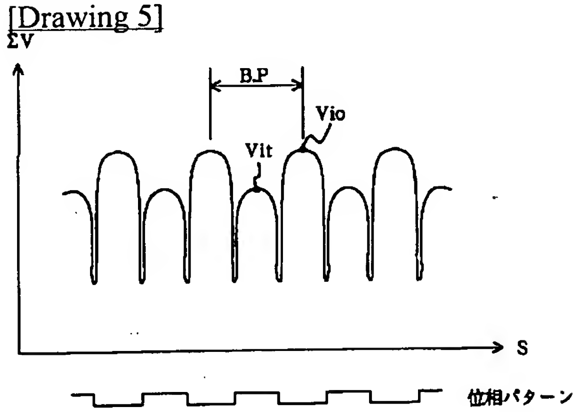
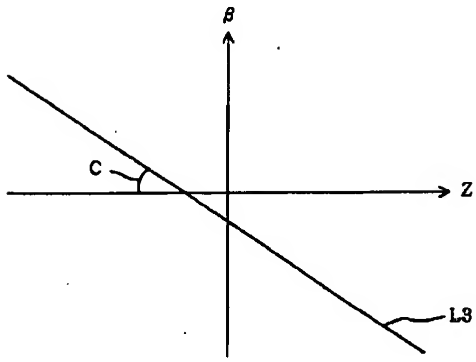
[Drawing 5]



[Drawing 4]



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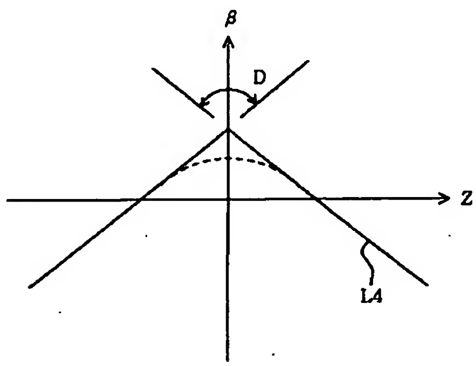

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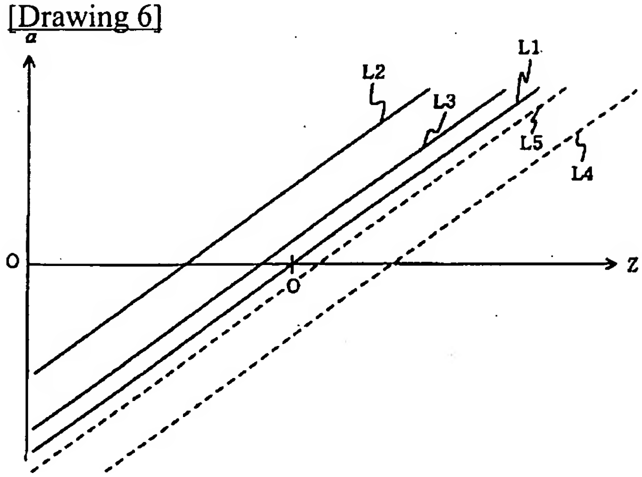
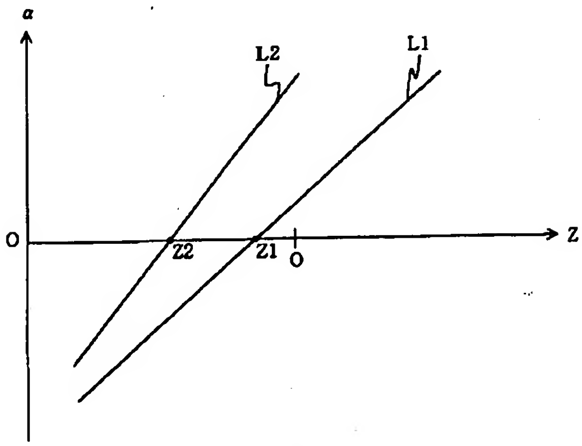
[Drawing 6]



[Drawing 7]



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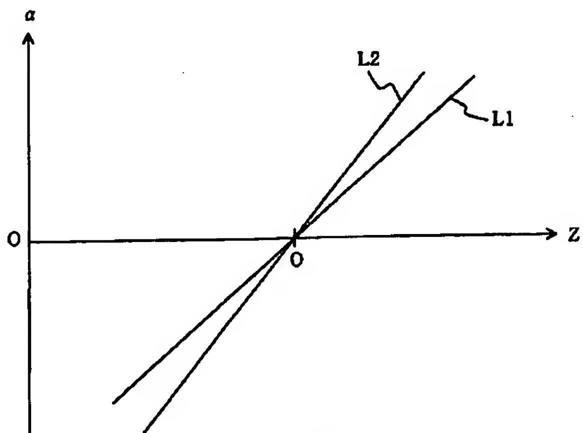
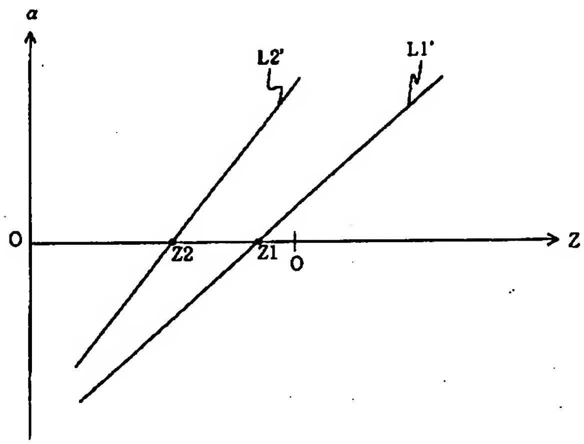


(b)

[Drawing 8]



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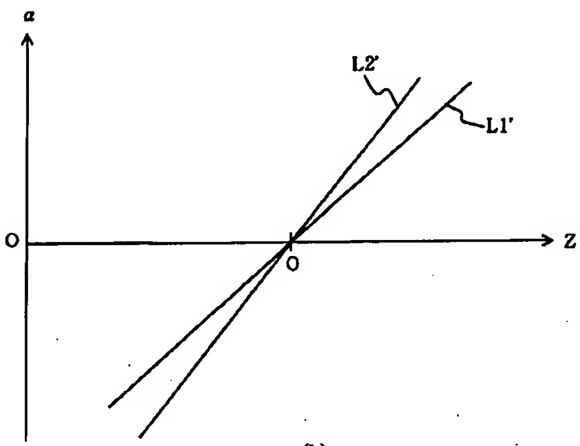
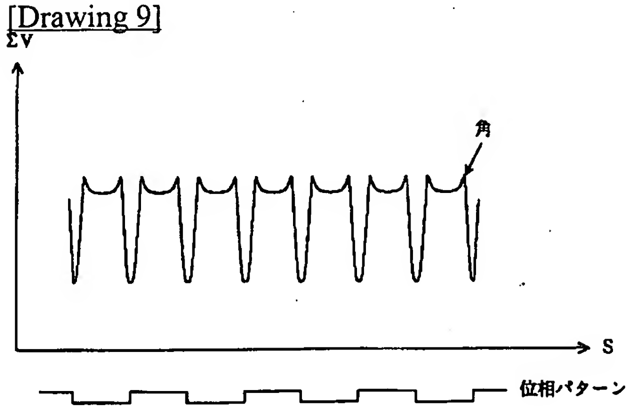
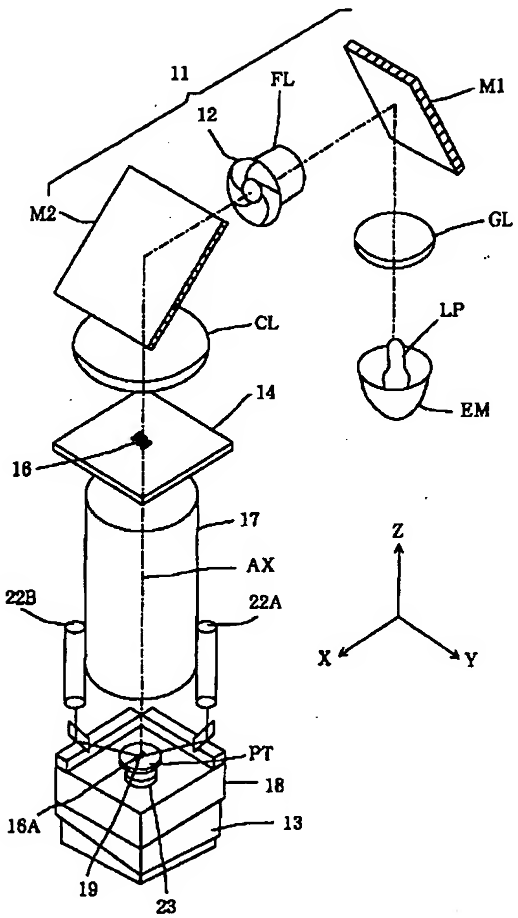


(b)

[Drawing 9]



[Drawing 10]



[Translation done.]